Geological Monitoring

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Cover: Speleothems located at the bottom of a shaft (known as the “National Geographic Ladder Pit”) that drops down from the Big Room into Lower Cave section of Carlsbad Cavern, Carlsbad Caverns National Park, New Mexico, USA. Photo by Ronal C. Kerbo, 2006. Back cover, counterclockwise from top left: Great Sand Dunes National Park (National Park Service [NPS] photo); stream gage monitoring (U.S. Geological Survey photo); repeat photography of glaciers at Denali National Park and Preserve (NPS photo taken by G.W. Adema); scuba diving in Carmen, Agusan del Norte (Wikimedia Commons photo taken by Historianurian, 2008, Creative Commons, http://creativecommons.org/licenses/by-sa/3.0/); fossil wasp, Palaeovespa florissantia at Florissant Fossil Beds National Monument (NPS photo); Furnace Creek, Death Valley National Park (NPS photo taken by Dave Steensen); stone rings, Svalbard (Wikimedia Commons photo taken by Hans Grobe, 2007, Creative Commons, http://creativecommons.org/licenses/by-sa/2.5/); lava flow at Hawaii Volcanoes National Park (NPS photo); Geoscientist-in-the-Park participant Cherith Janes monitoring at Sleeping Bear Dunes National Lakeshore (NPS photo); cave formations at Carlsbad Caverns National Park (NPS photo); geothermal features at Yellowstone National Park (NPS photo); Hebgen Lake, Montana earthquake, August 1959 (U.S. Geological Survey photo).

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Introduction

The Geologic Resources Division of the National Park Service initiated and funded the development of this manual to provide guidance for resource managers seeking to establish the status and trends of geologic resources and processes within the National Park System, and to further the understanding of how geologic processes impact ecosystem dynamics. This book is not intended to guide the inventory of geological resources, but rather to provide selected methods for the monitoring of long-term changes in those resources. In light of the reality of continuing global change, it is particularly important that land and resource managers have some perspective on the rate and nature of change within the physical environments they are managing. While the ultimate goal of most resource managers is to protect individual species, communities, or ecosystems, this cannot be done effectively without understanding the physical changes within the geological environment that may drive long-term ecosystem change.

Extensive input from geoscientists in a variety of federal agencies and educational institutions was included in each of the chapters in this manual. The purpose of the manual is to inform non-specialists on a range of techniques for monitoring the spectrum of geologic features and processes in the world around them; aid in the design and implementation of geologic monitoring programs on local, state, and federal lands; and provide a reference text for students studying and monitoring geologic processes. Many of the monitoring methods described in this book could also be used by teachers at all levels who are interested in involving their classes in monitoring the changes in a local geological resource (e.g., a stream near their school).

This book represents an effort to provide a variety of methodologies for use in monitoring important geologic resources; however, the methodologies provided within are not meant to be comprehensive. Quite the opposite, they have been selected from the pool of possible methodologies by a panel of subject experts. Our goal is to provide monitoring advice and support to managers and scientists who may not have geological expertise, but who have a need for geological monitoring. The volume includes chapters dedicated to specific critical geological resources (e.g., caves, glaciers, coastal areas). Within each chapter, you will find a justification for monitoring the resource, a listing of items that could be monitored (vital signs), and several possible methods for monitoring those vital signs. Where possible, we have provided methodologies that can meet all capabilities: from low-cost, low-expertise-required methods (level 1) to higher cost, higher expertise, detailed monitoring methods (level 3). Case studies are also presented, and each chapter includes a summary table of vital signs, methods, and costs that can be used as an easy reference for selecting monitoring methods.

This volume does not include methodologies for the monitoring of groundwater resources or chemistry, nor does it include any biological or ecosystem monitoring. Furthermore, due to space constraints, we have not attempted to detail each methodology within this book. Where details are not presented, references are provided to other published sources so that a methodology can be explored in more detail or so that additional case studies may be reviewed. Resources included in the book are:

- Aeolian resources
  - Frequency and magnitude of dust storms
  - Rate of dust deposition
  - Rate of sand transport
  - Wind erosion rate
  - Changes in total area occupied by sand dunes
  - Area of stabilized and active dunes
  - Dune morphology and morphometry
  - Dune field sediment state
  - Rates of dune migration
  - Erosion and deposition patterns on dunes
- Cave resources
  - Cave meteorology
  - Airborne sedimentation
  - Direct visitor impacts
  - Permanent or seasonal ice
  - Cave drip and pool water
  - Microbiology
  - Stability (e.g., breakdown)
  - Mineral growth
  - Surface expressions and processes
  - Groundwater levels and quality
  - Fluvial processes
- Coastal resources
  - Shoreline change
  - Coastal dune geomorphology
  - Coastal vegetation cover
  - Topography and elevation
  - Composition of beach material
  - Coastal wetland position and acreage
  - Coastal wetland accretion
- Fluvial resources
  - Watershed landscape
  - Hydrology
  - Sediment transport
  - Channel: cross section
  - Channel: planform
  - Channel: longitudinal profile
- Geothermal resources
  - Thermal feature location
  - Thermal feature extent
  - Temperature and heat flow
  - Thermal water discharge
  - Fluid chemistry
- Glacial resources
  - Glacier mass balance
  - Glacier terminus position
  - Glacier area
  - Glacier velocity
- Marine resources
  - Bathymetry
  - Hydrography
  - Barriers: reefs
  - Barriers: other
  - Substrate
  - Water column
- Paleontological resources
  - Erosion (geologic factors)
  - Erosion (climatic factors)
  - Catastrophic geohazards
  - Hydrology and bathymetry
  - Human access and public use
- Permafrost
  - Thermal state
  - Physical conditions
- Seismic resources
  - Monitoring earthquakes
  - Earthquake activity
  - Historical and prehistoric earthquake activity
  - Earthquake risk estimation
  - Geodetic monitoring, ground deformation
  - Geomorphic and geologic indications of active tectonics
- Slope movements
  - Types of landslides
  - Landslide triggers and causes
  - Geologic materials in landslides
  - Measurement of landslide movement
  - Assessing landslide hazards and risks
- Volcanic resources
  - Earthquake activity
  - Ground deformation
  - Gas emission at ground level
  - Emission of gas plumes and ash clouds
  - Hydrologic activity
  - Slope instability

Local, state, and national land managers are tasked with recognizing, observing, and understanding the ecological changes that are taking place on the lands they manage and using that information to modify their actions and to advance sustainable practices. The key is to begin with a good natural resource inventory and then develop an ecological monitoring program to detect the critical elements or indicators of change in the natural systems. Yet too often, the driver of the ecosystem change (changes in the physical environment) is not monitored. Monitoring geological change is a critical part of adaptive management. The only way that an effective land manager can develop strategies for preserving key ecological assets is to understand how physical landscape changes are impacting those resources.

For example, through biological monitoring we know that the number of Piping Plovers is decreasing along U.S. barrier island shorelines. In order to preserve the bird, one needs to know the rate of change of the particular physical environment—the overwash fan—within which these Plovers flourish. These areas have been strongly impacted by both human activities and global change (sea-level rise). The only way that a resource manager can hope to protect and manage this threatened species, is to understand the rate and nature of change of the geologic environment upon which the bird is dependant.

Geological monitoring can be carried out for a number of reasons beyond the protection of biological resources. Of particular interest these days is the monitoring of geological hazards. A number of the chapters in this book cover geological aspects that could be considered both a resource and a hazard (e.g., volcanoes, fluvial systems, coasts). Geological hazards can impact both human infrastructure and ecosystem dynamics and pose safety hazards, making them particularly important targets for monitoring.

Geological monitoring can also be critical for managing important geological heritage sites (the Old Faithful geyser, or the fossils of Dinosaur National Monument). Finally, geological monitoring activities can be an excellent way to introduce students at all grade levels to the scientific method and to the tools scientists use to understand global change. We hope that this manual will prove a useful tool for all of the above.

How to Use This Manual

The book is arranged to be a relatively "rapid" reference. In other words, we don't expect that many people will read the entire volume from cover to cover, although we would be thrilled for you to do so. Rather, we anticipate that users will turn directly to the chapter that interests them. All chapters have identical formatting to make them easy to use. Each chapter contains an overview of the resource and provides some background on the benefits of monitoring that particular resource.

The bulk of each chapter contains recommended methodologies for monitoring the vital signs listed above. Therefore, one can use this manual to gain the technical information necessary to plan the implementation of a monitoring program for documenting the impacts, for example, of global warming on a geologic resource such as the glaciers in Glacier National Park. Or, a resource manager may already know that he or she would like to monitor glacier mass balance. In that case, the user may simply turn directly to the section on that vital sign to find a detailed description of the vital sign, a variety of monitoring methodologies requiring varying costs and staff expertise, and references to case studies. In either case, we hope that you will find this a useful guide to the monitoring of geological resources on multiple levels.

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